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Research paper

Discovery of the chitinozoans *Belonechitina capitata* from the Shiala Formation of northeastern Garhwal-Kumaon Tethys Himalaya, Pithoragarh District, Uttrakhand, India

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ABSTRACT

Belonechitina capitata, a typically middle to late Ordovician chitinozoan index taxon was for the first time recovered from the northeastern Kumaon region, a part of Garhwal-Kumaon Tethys basin of the Himalaya, India. This species is of great biostratigraphic importance and has already been reported from Avalonia, Baltica and northern Gondwana. The study area was during Ordovician, part of a low-palaeolatitudinal Gondwana region. The vesicles of recovered forms are black and fragmentary. This is principally attributed to intense tectonic activity during the Himalayan orogenic movement which resulted into high thermal alteration. The chitinozoans are found along with melanosclerites.

1. Introduction

Chitinozoans are organic-walled microfossils characteristic of lower and middle Palaeozoic marine sediments and found either as single vesicle or in chain-like structures (Paris et al., 1999). These microfossils are well established for their high-resolution temporal record and stratigraphic tool (Wang et al., 2013). Their spatial distribution can be utilized for environmental reconstructions (Vandenbroucke et al., 2010), but their biological affinity is still poorly understood. The hypothesis mostly proposed in literature relates chitinozoans to eggs of non-fossilising metazoans, referred to as chtinozoophorans (Paris et al., 1999). However, Vandenbroucke et al. (2010) confirmed that chitinozoans were epiplanktonic. Recent studies proved that these microfossils are composed of a kerogen network with intense aromatic C=C ring and less intense aliphatic CH_x and oxygen- or nitrogen-bearing compounds (Jacob et al., 2007; Dutta et al., 2013).

The lower Palaeozoic sequence of northern India is situated tectonically in the Tethyan Himalaya, and was deposited on a part of the Gondwana palaeocontinent situated at relatively low palaeolatitudes i.e. ~25° to 30°S (Torsvik and Cocks, 2009). Although, Khanna and Sah (1983) and Khanna et al. (1985) had previously reported the presence of chitinozoans from the Tethys Himalaya, no detailed study on those chitinozoans were provided. It is not until 2011, chitinozoans were reported for the first time, with no doubt, by Sinha et al. (2011) from the Ordovician Shiala Formation in the Garhwal part of the Tethyan Himalaya. In their discovery two Ordovician index taxa: *Belonechitina capitata* and *Belonechitina micracantha* were reported.

2. Stratigraphy and sampling

In 2012, joint expedition-cum-geological field work was carried out in a seemingly continuous Cambrian, Ordovician and Silurian sequence along the Kali and the Kuthi rivers in the northeastern margin of Kumaon Province of the Uttarakhand State (Fig. 1). This area in the Tethyan Himalaya is adjacent to the Garhwal part which has been studied earlier (Sinha et al., 2011). The lower Palaeozoic units are well exposed along the river sections and comprise in ascending stratigraphic order the Garbyang, the Shiala, the Yong

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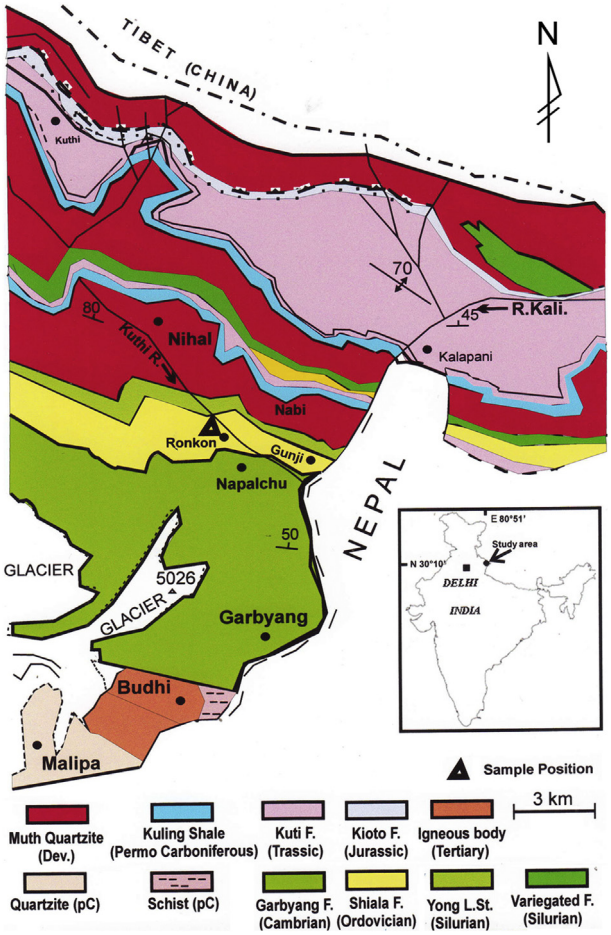

Figure 1. Geological map of the Garbyang–Gunji-Kali and Ronkon-Kuthi River area of Northeastern Kumaon, Tethys Himalaya, Pithoragarh District (Uttarakhand), India (after Sinha, 1989).

Limestone and the Variegated formations. The primary objective of this work was to collect rock samples and related data from both the Kali and the Kuthi sections and to look for chitinozoans and other acid-insoluble organic remains in this part of the Indian subcontinent. The maceration of selected samples yielded both chitinozoans and melanosclerites. Although only two chitinozoan taxa have been recovered after processing (Table 1) from the Ronkon-Kuthi (RK) river section of which *B. capitata* has biostratigraphical importance. *B. capitata* is described and illustrated together with melanosclerites in this paper with a brief stratigraphic note. The yield of chitinozoa is rare from Gunji-Kali (GK) river section. Hence, this paper describes chitinozoans from the Ronkon-Kuthi river section only.

The lower Palaeozoic sequence is well exposed in and around the Gunji and Ronkon villages (Fig. 1), are located in the Pithoragarh district of the Uttarakhand state at about 3440 m above m.s.l. Gunji can be reached by following the road from Bareilly, passing the towns Pithoragarh and Dharchula (N29°50′–E80°32′) up to Gala, and from there 40 km along an ascending mule track. Ronkon is located 3 km NW of Gunji.

The sample positions are shown in the lithology drawn from the Ronkon–Kuthi section (Fig. 2). At Ronkon village, part of the Shiala Formation and the base of the Yong Limestone Formation are exposed in the downstream part of the Kuthi river. The exposed thickness of the Shiala and the Yong Limestone formations are 11 m and <1 m, respectively (Fig. 2).

Table 1
Absolute abundances from the productive samples in the Ronkon-Kuthi River section.

Formation	Shiala	
Sample number	RK-13	RK-18
Palynological preparation number	13-2629	13-2630
Belonechitina capitata	12	37
Desmochitina spp.	2	–
Chitinozoan extracted	14	37
Sample size (g)	20.76	20.75
Chitinozoans per gram	0.6	1.8
Any other information	Internal pyrite growth in the form of internal molds.	Pyrite crystals stuck on the tegument of chitinozoan vesicle.

Heim and Gansser (1939) described the "Shiala Series" as a 400–500 m thick sandy shale intercalated with grayish marly limestones containing invertebrate fossils. Later, Gansser (1964) renamed the unit "Shiala Formation". The unit is essentially composed of calcareous shale, silty shale and interbedded fossiliferous limestone. Several fossils groups such as brachiopods, bryozoans (Shah and Sinha, 1974; Goel et al., 1987a), conodonts (Goel et al., 1987b), acritarchs (Sinha et al., 1998), chitinozoans (Sinha et al., 2011), and melanosclerites (Sinha and Trampisch, 2013a,b) have been reported. The Shiala Formation is conformably overlain by biostromal limestone referred to the Yong Limestone Formation

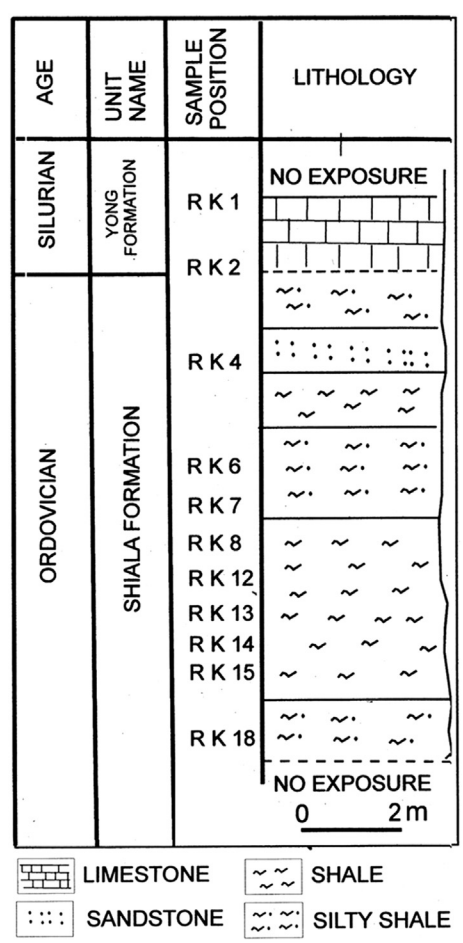

Figure 2. Stratigraphic log of the Shiala and Yong Limestone formations in the Ronkon-Kuthi River section showing sample positions.

(Shah and Sinha, 1974). The formation is characterized by a reefal structure, with a greyish-green biostromal limestone along with a fine grained limestone. The reefal core contains thin layers of calcareous mud and margins intercalated with thin shale bands (Khanna et al., 1985). The biota in the reef consists of calcareous branching algae, crinoids, corals, stromatoporoids and bryozoans.

3. Material and methods

Abundant chitinozoans and melanosclerites have been recovered from the Shiala Formation of the Ronkon-Kuthi river section. In fact, the yield of fossils is confined to several discrete horizons, possibly due to apparent sea-floor oxidation or other palaeoenvironmental constraints (Butcher et al., 2010). The fresh rock samples, mainly silty shale and limestone, collected from the Shiala and the Yong Limestone formations, were treated according to the standard palynological preparation techniques for Palaeozoic rocks (Paris, 1981). The samples RK13 and RK18, studied for chitinozoans under SEM were taken from the Shiala Formation.

Permanent slides for examination under light microscope (Leica DM2500) were prepared and stored in the Geology Department of Vinoba Bhave University (VBU), Hazaribag. Approximately 20 g of three productive shale samples were macerated for chitinozoans recovery and examination under a JEOL 6400 SEM at Ghent University, Belgium. The sample number RK13 yielded 14 chitinozoans. However, much pyrite is observed to have grown internally in the form of internal molds. Chitinozoans are only identified by external features on the tegument. The pyrite growth is hampering easy identification (Fig. 5A, H). The second sample number RK18, yielded 37 chitinozoans also with pyrite crystals stuck on the tegument of the chitinozoan (Fig. 5D) (see Table 1).

4. Results from the chitinozoans and discussion

Shah and Sinha (1974) and Sinha (1989) assigned a middle to late Ordovician age to the Shiala Formation based on index taxa of brachiopods and bryozoans. Goel et al. (1987a) dated it as Caradoc based on the conodont index species *Amorphognotus tvaerensis*. Sinha et al. (1998) recorded a rich and prolific assemblage of acritarchs from the Shiala Formation of Garhwal Tethys Himalaya and found that the Ordovician–Silurian boundary lies within the upper part of the Shiala Formation. Sinha et al. (2011) recorded late Ordovician chitinozoans from below the Ordovician–Silurian boundary in the same section. Sinha and Trampisch (2013a,b)

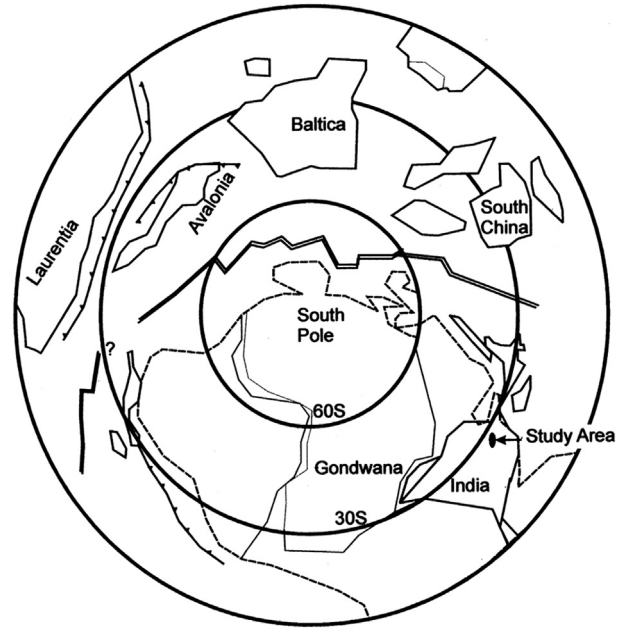

Figure 4. The recovered *Belonechitina capitata* from the study area has been shown in the late Ordovician palaeogeographic terrane map of Cocks and Torsvik, 2004 (after Vandenbroucke et al., 2010). This specimen has been reported from Avalonia, Baltica and northern Gondwana.

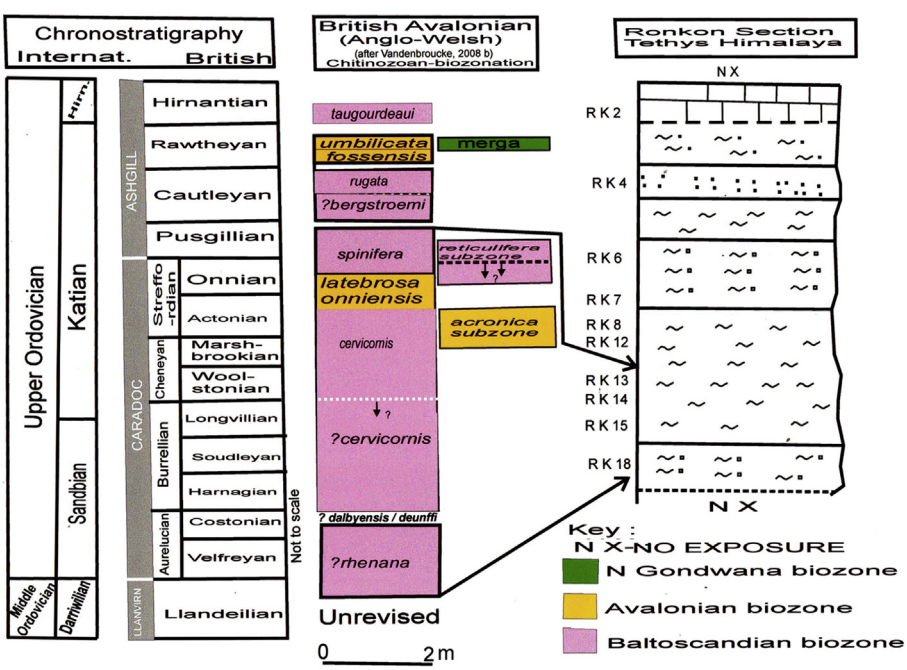

Figure 3. Attempted correlation of the Shiala formation at Ronkon-Kuthi River section, Tethys Himalayas (northern Gondwana) for the index specimen *Belonechitina capitata* with upper middle to late Ordovician chitinozoans biozonation which has a predominantly Baltoscandic signature, supplemented with Avalonian elements (after Vandenbroucke, 2008b).

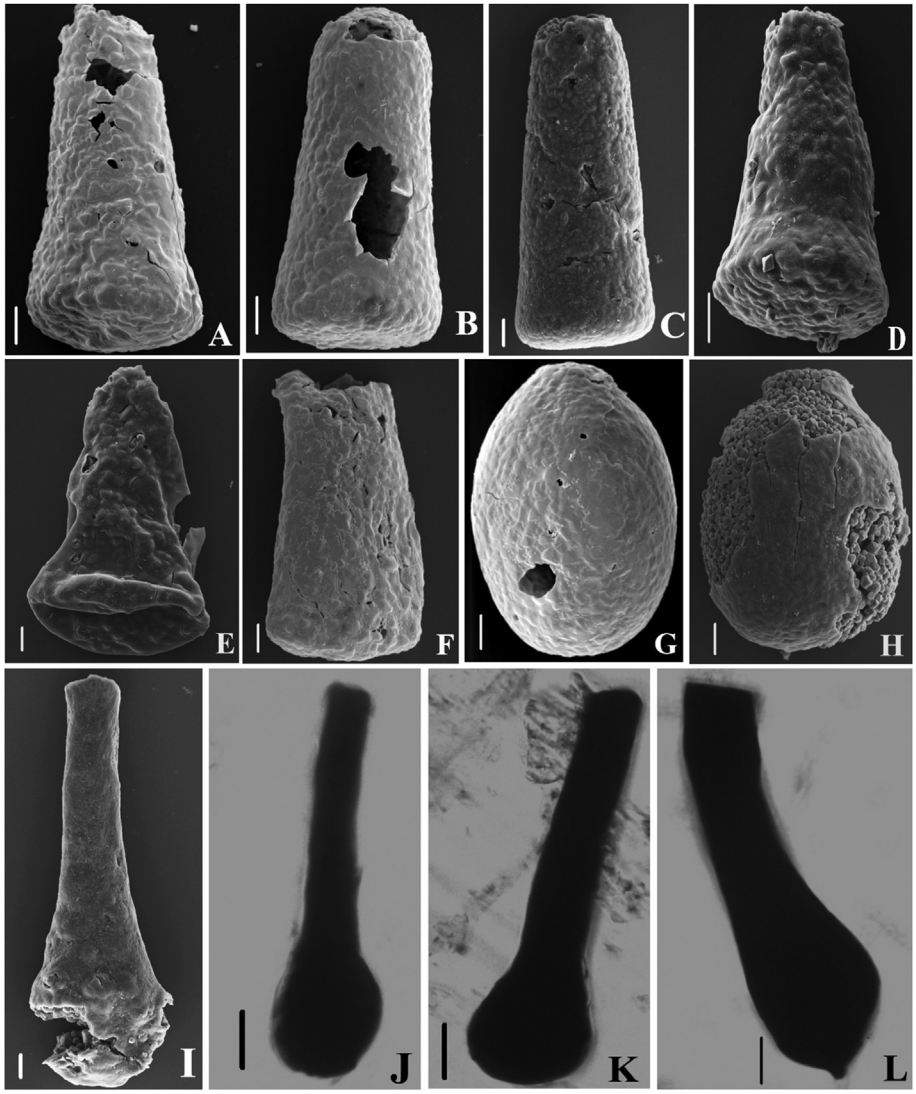

Figure 5. SEM photographs A–H. *Belonechitina capitata*. All measurements in micrometers (L × D_p, or L × D_p × D_c). Abbreviations (cf. Paris, 1981): L–total length, D_p–chamber diameter, D_c–diameter of oral tube. A: *Belonechitina capitata* (sample RK-13); 120 × 58 × 35. B: *Belonechitina capitata* (sample RK-13); 115 × 55 × 40. C: *Belonechitina capitata* (sample RK-13); 160 × 68 × 40. D: *Belonechitina capitata* (sample RK-18); 100 × 70 × 32. E: Deformed *Belonechitina capitata* (sample RK-18); 140 × 85 – L × D_p. F: *Belonechitina capitata* (sample RK-13); 112 × 60 × 42. G: *Desmochitina* spp., the collarette is weakly developed (sample RK-13); 117 × 78 × 30. H: *Desmochitina* spp. with fine pyrite crystals grown inside (sample RK-13); 124 × 85 × 35. I: SEM photograph of melanosclerite *Melanoporella bulla* (sample RK-18); 245 × 80 × 32. J: Light microscope (Leica DM2500) photograph of melanosclerite *Melanoporella bulla* (sample RK-18D); 103 × 57. K: Light microscope photograph of melanosclerite *Melanoporella bulla* (sample RK18D); 101 × 41.5. L: Light microscope photograph of melanosclerite *Melanosteus* sp (sample RK-13A); 111 × 68. Bar = 10 μm for all photographs.

reported melanosclerites of late Ordovician and algae of Silurian age from this formation.

Previously, Heim and Gansser (1939) had referred Yong Limestone Formation as 'Nodular Limestone' and Dave and Rawat (1968) referred to it as the Somna Series. The formation has been assigned a late Ordovician to early Silurian (Caradoc to Llandovery) age on the basis of floral and faunal content (Shah and Sinha, 1974). Sinha et al. (1998) assigned a middle to late Silurian age for the formation based on acritarchs.

The macerated samples RK (Ronkon-Kuthi river section) 13 and 18 yielded chitinozoans as well as melanosclerites. The recovered palynomorphs are moderately to poorly preserved, black in colour and commonly fragmented. It is interpreted as a result of a considerably intense thermal alteration, resulting from a high level of diagenesis or low metamorphism due to orogenic movement of the Himalaya. The presence of pyrite in all recovered chitinozoans indicate a reducing and poorly oxygenated, low energy environment of deposition and early diagenesis. It is known that a reducing environment favours the preservation of oxygen matter and produces iron sulphide minerals (Chaiffetz, 1978).

The melanosclerite assemblages consist of *Melanoporella bulla* (Fig. 5I, J, K) and *Melanosteus* sp. (Fig. 5L). The recovered assemblage of chitinozoan is mainly dominated by *B. capitata* (Fig. 5A–F) from the samples RK13 and 18.

Eisenack (1962) firstly described *B. capitata*. A close perusal of literature on this species of *Belonechitina* reveals that this is indicative of a time range from the upper Darriwillian to the lower Sandbian (Nõlvak and Grahn, 1993). *B. capitata* reported from the Baltoscandic *Fungochitina spinifera* Biozone (Nõlvak and Grahn, 1993) along with *Saharochitina fungiformis*, has a short range and is not encountered in the *Armoricochitina reticulifera* subzone, which has a Onnian-Pusgillian (Katian) age (Fig. 3). Below follows the detailed description of *B. capitata* recovered from this study,

Group CHITINOZOA (Eisenack, 1931)

Order PROSOMATIFERA (Eisenack, 1972)
Family CONOCHITINIDAE (Eisenack, 1931 emend. Paris, 1981)
Subfamily *Belonechitininae* (Paris, 1981)
Genus *Belonechitina* Jansonius, 1964 emend. (Paris et al., 1999)
Type species *Conochitina micracantha* subsp. *robusta* (Eisenack, 1959)
B. capitata (Eisenack, 1962)

Material: 12 specimens from samples RK-13; 37 specimens from samples RK-18 (both samples from the Shiala Formation).
Dimensions: L (total length in μm): 92-125-160; Dp (chamber diameter in μm):58-75-85; Dc (diameter of oral tube in μm):28-32-45.
Description: Vesicle cylindrico-conical, elongated without flexure and a rounded basal margin. The vesicle wall is smooth, with simple blunt spines observed in some specimens near basal part. The convex base possesses a short, circular, button-like mucron in some specimens, a central depression. No operculum or prosome has been observed.
Discussion: The specimens of this study do not have a widened, conical base as described in holotype of Eisenack (1962).

4.1. Discussion on the biostratigraphy

B. capitata was reported by Vandenbroucke (2008a) in the Aurelucian, Burellian, Cheneyan, Onnian (all Caradoc–Sandbian to Katian) and Pusgillian (Ashgill) of the British historical type areas of the Ordovician in UK.

B. capitata occurs in Baltoscandia from the Lasnamägi (upper Llanvirn, upper Darriwilian) to the Nabala stage (upper Caradoc, middle Katian) (Nõlvak and Grahn, 1993). In northern Gondwana, it has been reported a.o. from the upper Llanvirn (upper Darriwilian) and lower Caradoc (lower Sandbian) of Portugal (Henry et al., 1974; Paris, 1981), Saudi Arabia (Al-Hajri, 1995), and the Algerian Sahara (Oulebsir, 1992). Vandenbroucke et al. (2005) reported it on Avalonia from Caradoc (Sandbian–middle Katian) strata. This species has been recovered from the Shiala Formation of Chamoli district of Garhwal Tethys Himalaya, India along with *B. micracantha*, transitional forms *B. capitata* and *B. micracantha*, *Belonechitina* spp., *Conochitina chydaea*, *Conochitina* spp., *Conochitinidae*, *Angochitina* spp. suggesting a middle–late Ordovician age (Sinha et al., 2011). However, only two forms of chitinozoans have been recovered from Kumaon region.

The study area was part of a low-palaeolatitudinal Gondwana i.e., at ~25° to 30°S during the Ordovician–Silurian (Torsvik and Cocks, 2009). Interestingly, chitinozoans of Ordovician–Silurian time are well studied and established in high palaeolatitudinal regions of the globe, except Illinois, USA and Anticosti Island, Canada. During the late Ordovician and early Silurian, North America was the major part of the palaeocontinent of Laurentia (Cocks and Torsvik, 2002; Butcher et al., 2010) and Illinois area was situated about 20° South of equator (Kluessendorf and Mikulic, 1996). The Anticosti Basin of Canada was situated at palaeolatitude 10°–15°S during late Ordovician (Cocks and Torsvik, 2004). Achab et al. (2011) reported various *Belonechitina* related species from the entire succession of Ellis Bay Formation of Anticosti Island, Canada.

B. capitata is an index fossil for a larger period of Late Ordovician (most of the Caradoc and lowermost Ashgillin UK), but not a short time range index fossil of any of the substages of that period. Hence, it is a typically middle to late Ordovician chitinozoan index taxon (Vandenbroucke, 2008a). It has been recovered from wide palaeogeographical provinces from Avalonia, Baltica to northern Gondwana (Figs. 3 and 4) which reveals a wide palaeogeographic distribution from a low to a high palaeolatitude during late Ordovician time. Several chitinozoan Biotopes have been established based on their spatial distributions which signifies that the palaeogeographical boundaries were climatic-sensitive during late Ordovician (Vandenbroucke et al., 2010). *B. capitata* is representative of the Biotope III which has a broad latitudinal range from 30° or 35°S to 60°–80°S (Vandenbroucke et al., 2010) which attributes to a hypothetical Transition to Polar plankton provinces (Vandenbroucke et al., 2009). However, several oceanographic boundaries have been identified by Vandenbroucke et al. (2010) in which 35°S was representative of Subtropical-Subpolar Transitional climate which prevailed during late Ordovician. The study area was situated at ~25° to 30°S as stated, which can be identified and correlatable with a tentative Subtropical-Subpolar Transitional palaeoenvironment for the recovered *B. capitata* (Fig. 4).

The recovered melanosclerites *M. bulla* has been described from Ordovician sediments (Trampisch, 2007; Sinha and Trampisch, 2013a). However, other form *Melanosteus* sp. could not be identified at the specific level due to monospecific yield. Detailed study of melanosclerites from this section will be documented in further work.

5. Conclusions

(1) The present discovery is the first definite record of Ordovician chitinozoan *B. capitata* from the northeastern Kumaon region, which is a part of Garhwal-Kumaon Tethys Himalaya.
(2) The present study confirms that *B. capitata* has a wide latitudinal range extending from northern Gondwana, over Avalonia to Baltica, representative of Biotope III (palaelatitude 30°–60°S) and suggest it is a useful boistratigraphic index fossil of the middle to late Ordovician.
(3) The recovered fauna is commonly fragmentary with black vesicles. This points to the considerable thermal exposure shown by the high degree of diagenesis or low grade metamorphism during deep burial and later tectonics history of the Himalaya.
(4) Chitinozoans recovered from discrete horizons in the present study can be included into one biozone, whereas at least two and more forms have been recovered from the Garhwal region. Such a faunal difference from the same formation, can possibly be attributed either to a lateral variation in the local physical factors of the deposition of the formation or to a sampling effect by locally sampling in a different part of the formation. For a better understanding of this variation, more palynological materials need to be collected and studied.

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